# Anatomy of Flowering Plants

# 6

## INTRODUCTION

- Anatomy is the branch which deals with the study of **gross internal structure** of plant organs as observed after section cutting.
- Study of this branch started in 1671, when **Marcello Malpighi** and **Nehemiah Grew** independently studied the anatomy of vegetable plants.
- **Nehemiah Grew** is known as **'Father of plant anatomy'.**
- **K.A. Chaudhary** is known as **'Father of Indian plant anatomy'.**

## TISSUE

- A group of cells having a common origin and performing a similar function.
- The term tissue was coined by **Nehemiah Grew.**

## TYPES OF TISSUES

Tissues may be classified into two groups : Based on whether the cells being formed are capable of dividing or not

A. Meristematic tissues

B. Permanent tissues

### A. MERISTEMATIC TISSUES (MERISTEMS):

- The term **meristem** has been derived from a Greek word **meristos –** which means **divisible** or having cell division activity, so meristem is a **group of cells which has power of continuous division.**

  e.g.; meristem at apex of stem, root and vascular cambium, etc.
- The term **meristem** was given by **C. Nageli** (1858) for group of continuously dividing cells.
- In multicellular organisms, growth is limited to specific regions. These areas are called **meristems.**
- The cells of meristematic zone are capable of division until death.

**The characteristics of meristematic cells are as follows :**

- The cell of meristematic tissue are always **living** and found in **vegetative regions** of the plant.
- They have thin walls of **cellulose.**
- Cells are normally **isodiametric, oval, polygonal** or **rectangular.**
- **Abundant cytoplasm** is present.

- Cells are **compactly arranged** and **lack intercellular spaces.**
- Cells have the **capacity to divide.**
- Vacuoles are either **absent** or **very small.**
- Large prominent **nucleus is present.**
- They have no reserve food material and further no ER and plastids in them.

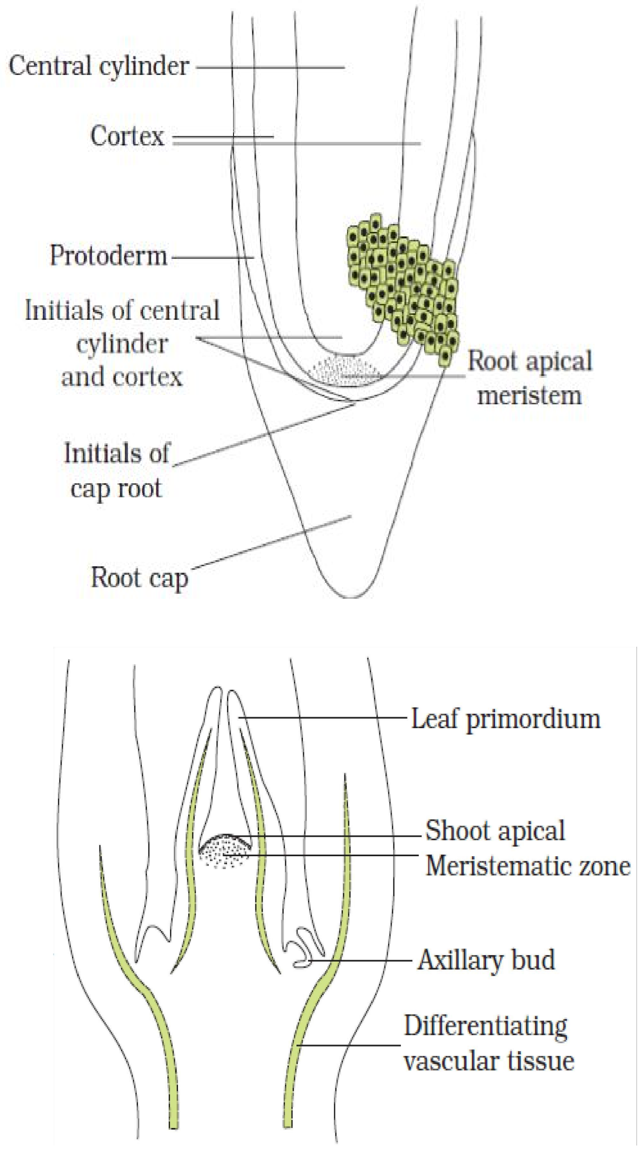



**Figure** - Apical meristem: (a) Root (b) Shoot

## CLASSIFICATION OF MERISTEMATIC TISSUE :

Meristematic tissues may be classified on the basis of :

(a) Origin and development

(b) Position in the plant body

(c) Plane of division

(d) Functions

**(a) Meristems based on origin and development :**

On the above basis meristems can be divided into following three types :

**(i) Promeristem ( = primordial meristem )**

- A group of cells which represent primary stages of meristematic cells.
- They are present in a small region at the apices of **shoots** and **roots.**
- They give rise to **primary meristems.**

**(ii) Primary meristem**

- The meristematic cells that originate from promeristem are **primary meristems.**
- These cells are always in **active state of division** and give rise to **primary permanent tissues.**
- In most **monocots** and **herbaceous dicots,** only primary meristem is present.

**(iii) Secondary meristem**

- They are the meristems developed from **primary permanent tissue.**
- They are not present from the very beginning of the formation of an organ but develop at a later stage and give rise to **secondary permanent tissues.**

  Examples :– Cambium of roots, interfascicular cambium of stem and cork cambium.
- Secondary growth occurs due to the activity of these cells. It increases the thickness of the plant parts.
- It is generally found in **shrubs** and **trees.**

**(b) Meristems based on position in plant body :**

On the basis of position, the meristematic tissues can be divided into the following three types :

**(i) Apical meristem**

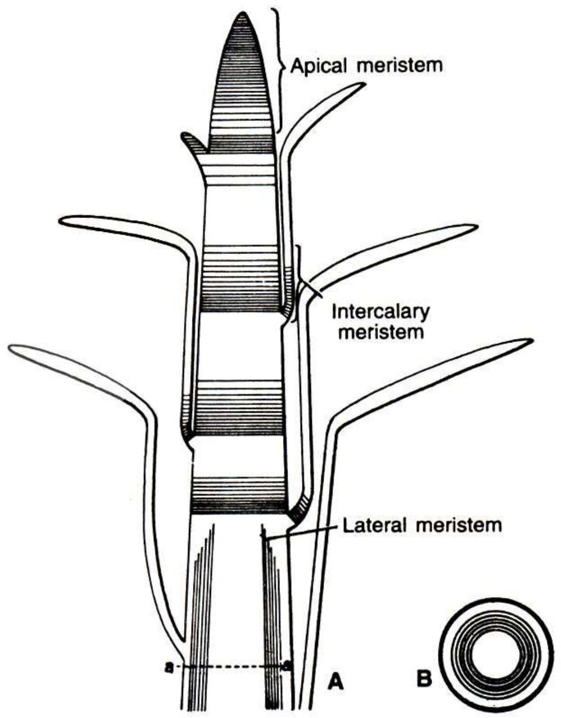
- It is found at the **apex** of growing points of root and shoot.
- It **divides continuously** and brings about growth in length of shoot and root.
- The apical meristem includes **promeristem** as well as **primary meristem.**

**(ii) Intercalary meristem**

- It is present away from apical meristem.
- It is present at the **base of internodes** e.g.; in grasses and wheat (Gramineae) or at the **base of leaves** e.g.; in pinus or at the **base of nodes** e.g.; mint or *Mentha* (Labiatae).
- It is responsible for **increase in length.**

**(iii) Lateral meristem**

- They are located **parallel to the long axis** of the plant organs.
- Their activity results in **increase of the diameter** of the plant organs. e.g.; **Cork cambium** and **Vascular cambium.**




**Different types of meristems on the basis of position in plant body**

**(c) Meristems based on plane of division :**

It includes three types of meristems :

**(i) Mass meristem :** In this cell division occur in **all planes** so that an irregular shaped structure is formed e.g. endosperm.

**(ii) Plate meristem :** It consist of parallel layers of cell which divide **anticlinally** in **two planes** so that a **plate–like structure** is formed. This pattern is seen in the development of leaf lamina.

**(iii) Rib meristem :** In this type, cells divide at **right angles** or **anticlinally** to the **longitudinal axis.** It is found in the development of cortex and pith.

**(d) Meristems based on function :**

**Haberlandt** (1980) recognized three categories of apical meristem. It is as follows :–

**(i) Protoderm :** It is the **outermost layer** of the young growing region which develops the **epidermal tissue system.**

**(ii) Procambium :** It is composed of **narrow, elongated cells** that give rise to the **vascular tissue system,** that is, xylem and phloem.

**(iii) Ground meristem :** It consists of **large, thin–walled cells** which develop to form **ground tissue system,** that is hypodermis, cortex and pith.

**B. PERMANENT TISSUES :**

- It is formed due to **division** and **differentiation** in meristematic tissue.
- The cells of this tissue may be **living** or **dead, thin–walled** or **thick–walled.**
- The thin walled tissues are generally **living** whereas the thick–walled tissues may be **living** or **dead.**

Permanent tissue can be of following types :

(a) Simple tissue

(b) Complex tissue

## (a) Simple tissues

These are homogeneous in nature and are composed of structurally and functionally similar cells.

These are of three types :

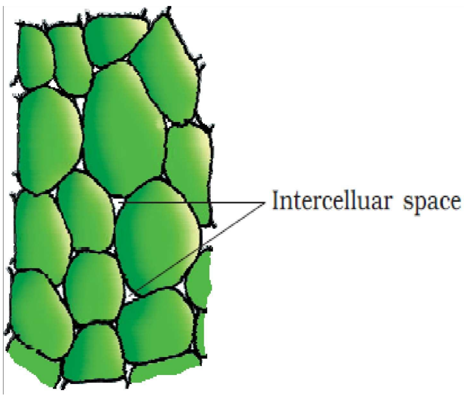
(i) Parenchyma

(ii) Collenchyma

(iii) Sclerenchyma

### (i) Parenchyma

- Parenchyma is considered as the **precursor** of all other living tissues. It is also the most **primitive tissue** from phylogenetic point of view.
- Parenchymatous cells are **living,thin–walled,** containing **distinct nuclei.**
- The cell walls are made up of **cellulose, hemicellulose** and **pectic** materials.
- Cells have **small** or **large** intercellular spaces.
- Cells are generally **isodiametric** (but may also be elongated, lobed and polygonal).
- Photosynthetic parenchyma contains **chloroplasts,** while the parenchyma present in underground parts contains **leucoplasts.**
- All meristems are made up of **parenchyma.**
- Parenchyma is usually present in **soft** and **fleshy** parts of plants.




**Parenchyma**

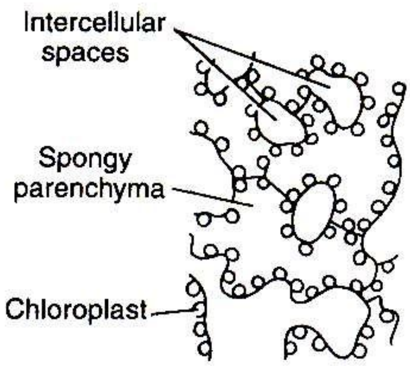
**Functions**

- Parenchyma cells are the centres of **respiration, photosynthesis, storage, secretion.** etc.
- These cells may have the **power of division.**
- These cells help in **wound – healing** and in formation of **adventitious buds** and **roots.**
- In aquatic plants parenchyma cells store air and provide **buoyancy to plants.**
- Parenchyma cells of xylem and phloem help in **conduction of water** and **food materials.**

## SPECIALIZED PARENCHYMA

**Chlorenchyma**

- When parenchyma cells contain chloroplasts, it is known as **chlorenchyma.**
- **Examples –** leaf mesophyll tissue, outer cortex of young stem, outer cortex of xerophytic stem etc.
- Its function is to manufacture **food material (photosynthesis).**



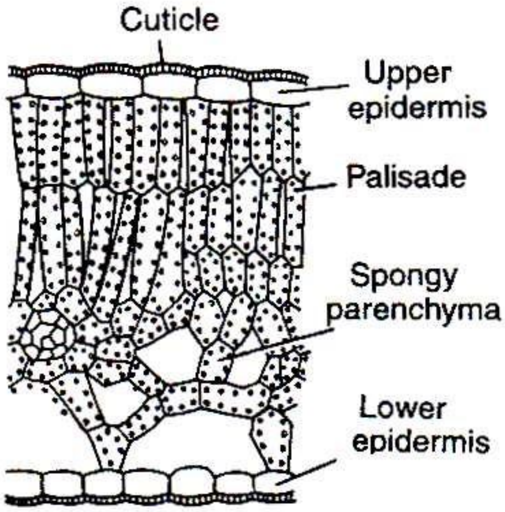

**Chlorenchyma**

**Palisade**

- Chlorenchyma whose cells are **columnar,** is called **palisade.**
- **Example –** Tissue below the upper epidermis in a dorsiventral leaf.

**Spongy parenchyma**

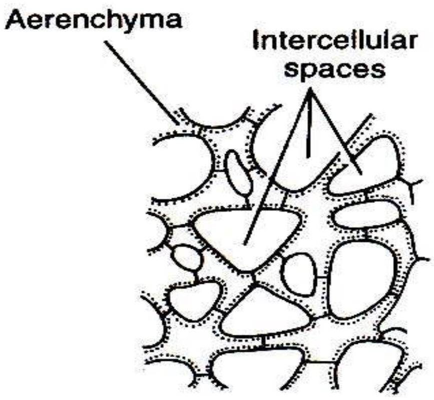
- Chlorenchyma having well defined **intercellular spaces.**
- **Example –** Tissue above the lower epidermis in a dorsiventral
  leaf.




**Palisade and spongy parenchyma**

**Aerenchyma**

- **In hydrophytes,** the parenchyma develop air spaces and such parenchyma with **air cavities** is known as **aerenchyma.**
- **Examples –** *Hydrilla* and *Eichhornia* etc.
- It helps hydrophytes **to float** and **provides $O_2$ for respiration.**



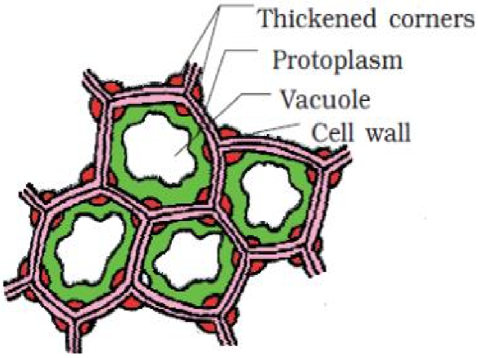

**Aerenchyma**

**Mucilaginous parenchyma**

- It has large **vacuoles** and **mucilage.** e.g. **Succulents.**
- Its function is **storage of water.**

**(ii) Collenchyma**

- Collenchyma word was given by **Schlieden (1839).**
- These are **living elongated cells** with **thick walls.**
- The cell wall is made up of **cellulose, hemicellulose** and **pectic materials.** The wall thickening is not uniform.
- The walls are often provided with **simple pits.**
- Sometimes chloroplasts are present in **collenchyma cells.**
- Collenchyma is found in many **herbaceous dicot stems,**
  **petioles** and **younger regions of woody stems.**
- Collenchyma is **absent in roots** and **monocot stems.**




**Collenchyma**

**Types of collenchyma**

On the basis of thickening on cell wall, collenchyma may be of three types :–

**A. Angular**

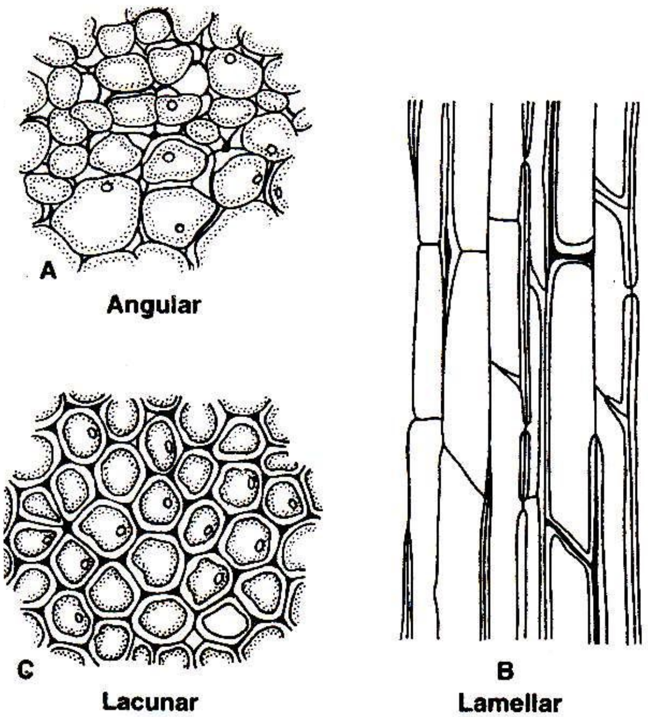
- The deposition is maximum at the angles (where the two cell walls come in contact).
- The cells appear **polygonal** in **transverse section.**
- It is the most common type, e.g.: – *Datura, Cucurbita, Solanum, Ficus, Vitis, Polygonum, Morus, Cannabis*, etc.

**B. Lacunar**

- Large **intercellular spaces** occur between the cells.
- The deposition occurs on the walls towards the spaces.
- The hollow thickened components are found. e.g.; – *Salvia, Malva, Althaea* etc.

**C. Lamellar**

- The deposition occurs on **tangential walls.**
- The cells appear **plate like** or **lamellar.** It is also called **plate collenchyma** e.g.;– *Rheum*, *Eupatorium* etc.




**Different types of collenchyma**

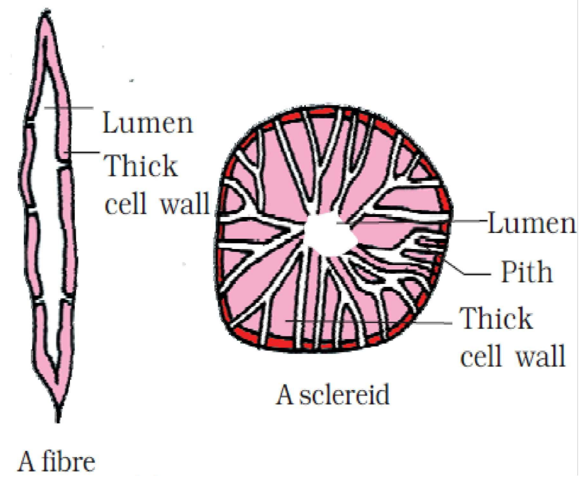
**A. Angular B. Lamellar C. Tubular or lacunar**

**Functions**

- It performs both **mechanical** as well as vital types of functions.
- Collenchyma provides **tensile strength** which gives elasticity and support to the growing organs.
- Chloroplast containing collenchyma performs **photosynthetic function.**

**(iii) Sclerenchyma (Greek : Scleras = hard)**

- They are **dead cells,** and act as **purely mechanical.**
- The cells are **long, narrow** and **pointed** at both ends.
- The cell walls are **lignified** and have **simple pits.**
- The cell walls are very **thick** with the result that the cell cavity becomes **narrow.**




**Sclerenchyma**

**Types of sclerenchyma**

A. Fibres or sclerenchymatous fibres

B. Sclereids or stone cells

**A. Fibres or sclerenchymatous fibres**

- Cells **long, narrow** and **thick walls, pointed at both ends** and **lignified.**
- Cell wall has **simple** or **bordered pits.** These are unthickened areas.

**Functions**

- Fibres give necessary **strength, rigidity, flexibility,** and **elasticity** to the plant body and thus enable it to withstand strains.

**B. Sclereids**

- These are not much longer than their breadth.
- They have also extremely thick wall of lignin with narrow lumen.
- The cells have no **definite shape.**

The sclereids are spherical, oval or cylindrical, highly thickened dead cells with very narrow cavities (lumen). These are commonly found in the fruit walls of nuts; pulp of fruits like guava, pear and sapota; seed coats of legumes and leaves of tea. Sclerenchyma provides mechanical support to organs.

**Functions**

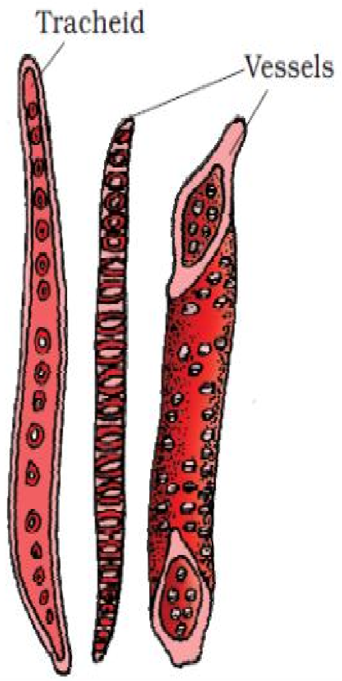
- Sclereids provides **mechanical strength** to the part of the plant where they are present. They contribute to the **firmness** and **hardness** of the part concerned. Develops **resistance in plant** against unfavourable conditions.

**(b) Complex tissues**

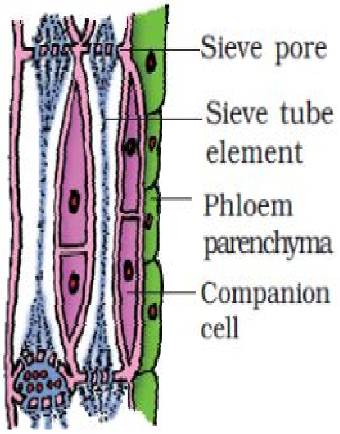
- The complex tissues are made up of **living** and **non – living cells** which perform different functions.
- The complex tissues act as **single units.**
- The complex tissues are also known as **vascular tissues.**

They are of two types :

(i) Xylem (ii) Phloem




**Xylem**




**Phloem tissues**

**(i) Xylem or wood**

- Xylem word was given by **Nageli (1858).**
- It is also called as **wood** because the major part of stem and root in vascular plants is constituted by xylem.
- The function of xylem is to **conduct water** and **mineral salts** upwards from the **root to the leaf** and to give **mechanical strength** to the plant body.
- It is a **conducting tissue** and is composed of four different kinds of elements :–

a. Tracheids b. Vessels

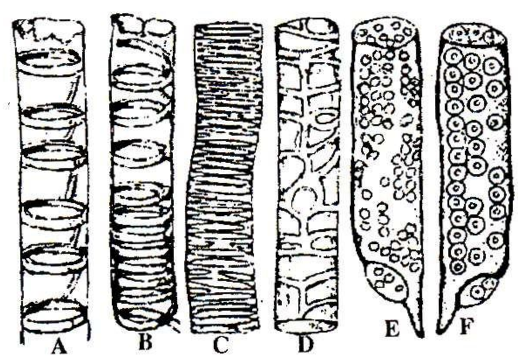
c. Wood fibres d. Wood parenchyma

**a. Tracheids**

- A single tracheid is highly **elongated** or **tube – like cell** with **hard, thick** and **lignified walls** and a **large cavity.**
- They are devoid of **protoplast** and hence **dead.**
- These are only constituents of the xylem of **primitive plants.**
- The secondary wall layers possess various kinds of thickenings in them and may be distinguished as **annular** (in the form of rings), **spiral, reticulate, scalariform** or **pitted** (simple or bordered).
- In a transverse section these appear either **circular, polygonal** or **polyhedral** in outline.
- Tracheids occur alone in the wood of **ferns** and **gymnosperms**, whereas in the wood of **angiosperms** they occur with the vessels.
- Tracheids are the only elements which are found in the **fossils** of **seed plants.**

**Functions**

- These carry out transport of **water, harmones** and **solutes** from the **root to the stem, leaves** and **floral parts.**
- It gives **mechanical support** to the plant body.




**Type of wall thickenings in vessels**

**b. Vessels**

- A vessel is a **long, cylindrical, tube–like structure** with **lignified walls** and a **wide central cavity.**
- The cells are **dead** and **without protoplast.**
- These are arranged in **longitudinal series** in which the **transverse walls** (the end plates) are perforated and as such the entire structure looks like a **water pipe.**
- The perforations may be **simple** (only one pore) or **multiple** (several pores).
- Vessels also have various type of thickenings similar to tracheids.
- Vessels are found only in some **pteridophytes** (e.g. *Pteridium, Selaginella*) and **gymnosperms** (e.g. *Ephedra, Gnetum*). However they are present in almost all angiosperms.

**Functions**

- They serve as a **more efficient** mode of **transport of water** and **minerals** as compared to tracheids due to the presence of **perforation plates.**
- These also give **mechanical support** to the plant body.

**c. Xylem fibres (Wood fibres)**

- Sclerenchymatous cells associated with xylem are called **xylem fibres.**
- They are **long, narrow, thick** and **lignified cells**; usually **pointed at both ends.**
- Xylem fibres are **dead cells.**

**Functions**

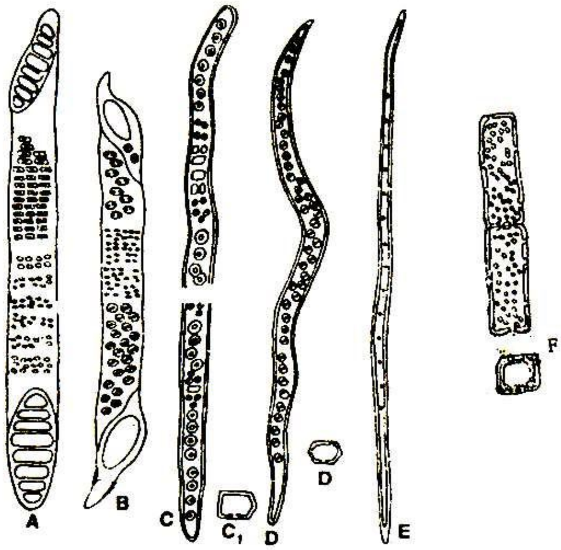
- Xylem fibres provide **mechanical strength** to the xylem and to the plant body as a whole.

**d. Xylem parenchyma (Wood parenchyma) :**

- The parenchymatous cells found in xylem are **living** and **isodiametric.**
- Xylem parenchyma cells are more common in primary xylem than secondary xylem.
- Xylem parenchyma cells of primary xylem are **thin–walled** and made up of **cellulose,** while those found in secondary xylem are **thick–walled** and made up of **lignin.**

**Functions**

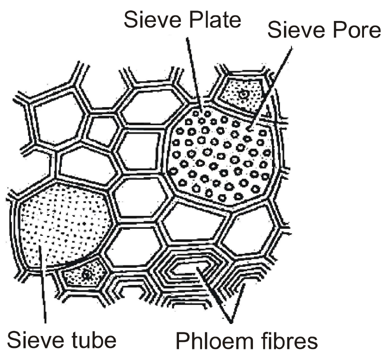
- It serves for **food storage.**
- It helps in the **conduction of water upwards.**



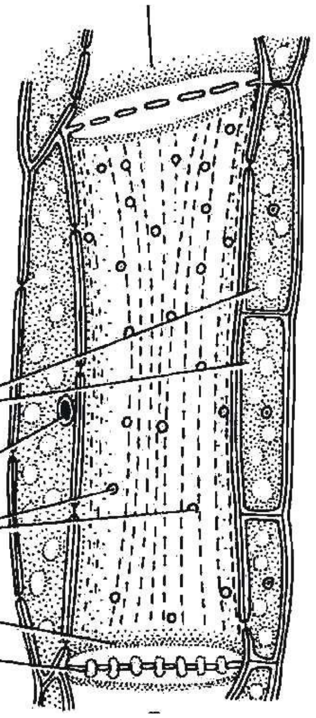

**A,B–Vessel, C,D–Tracheid, E–Fibre, F–Wood parenchyma**

**(ii) Phloem or bast**

- The term phloem was coined by **Nageli (1858).**
- Phloem is another type of **conducting tissue** like xylem which is responsible for conduction of organic substances.




**T.S. of phloem showing its elements**




**B. L.S. of phloem**

The phloem is composed of four elements :

(i) Sieve tube elements

(ii) Companion cells

(iii) Phloem parenchyma (Bast parenchyma)

(iv) Phloem fibres (Bast fibres)

**(i) Sieve tube elements**

- Sieve elements were discovered by **Hartig (1837).**
- Sieve tubes are **tube–like structures,** composed of **elongated cells,** arranged in **longitudinal series** and associated with **companion cells.**
- Their walls are **thin** and made of **cellulose.**
- In a mature sieve tube the nucleus is **absent** but **peripheral cytoplasm** as well as **large vacuole is present.**
- The uniqueness of the sieve tube is that although **without nucleus,** it is **living** and the **nucleus of the companion cells control its functional activities.**
- The transverse partition walls are perforated by a number of pores, giving the appearance of sieves. They are called the **sieve plates.**
- A sieve plate is called **simple** if it has only **one sieve area.** A sieve plate is called **compound** if it has **many sieve areas.**
- In **lower vascular plants** and **gymnosperms** in place of sieve tube elements, sieve cells are present.

**Functions**

- The main function of the sieve tubes is the transport of prepared food materials from leaves to the storage organs in the downward direction and then to growing regions in the upward direction.

**(ii) Companion cells**

- These are **specialised parenchyma cells** which are closely associated with the sieve tube elements in their **origin, position** and **function.**
- These originate from the same **meristematic cells** that give rise to the sieve tube elements.
- The sieve tube elements and companion cells are connected by pit fields present in their longitudinal walls, which is a common wall for both and with the death of one, the other cell also dies.
- The companion cell has **dense cytoplasm** and **prominent nucleus.**
- Its **nucleus** also controls the metabolic activities of the sieve tube.
- Companion cells are characteristic feature of **angiosperms.**

**Function**

- The companion cells play an important role in the maintenance of a **pressure gradient in the sieve tubes.**

**(iii) Phloem parenchyma (Bast parenchyma)**

- These are **living parenchymatous cells** which may be **cylindrical, sub–spherical** or **polyhedral** in shape.
- The cells have **dense cytoplasm** and **nucleus.**
- The cell–wall is composed of **cellulose.**

**Function**

- The main function of phloem parenchyma is the **storage of food material** and other substances such as **resin, tanin** and **mucilage.**

**(iv) Phloem fibres (Bast fibres)**

- These are much **elongated, unbranched** (rarely branched) and have **pointed, needle–like apices.**
- Their cell wall is quite thick with **simple** or **slightly bordered pits.**
- **At maturity** these fibres lose their protoplast and become **dead.**
- These occur in **groups** e.g.; in *Linum usitatissimum* (flax) and *Corchorus capsularis* (jute).

**Functions**

- The phloem fibres provide **mechanical support to the phloem.**
- The phloem fibres are economically very important as they are used in making cords, gunny bags, and coarse cloth.

## THE TISSUE SYSTEM

- The bodies of multicellular organisms are made up of different types of tissues.
- Like animals, division of labour is also found in plants.
- Thus different types of tissues perform different functions in plants.
- All the tissues are arranged in three systems.
- Each system may consist of only one tissue or a combination of tissues which may be similar or different in structure, but perform a common function and have the same origin.

**Types of tissue systems**

- It was **Sachs,** a **German scientist,** who for the first time in **1875** attempted to classify the tissues on the basis of their **position and morphology.**
- According to him, the following three categories of tissue systems can be distinctly identified:

  A. The epidermal tissue system.

  B. The ground or fundamental tissue system.

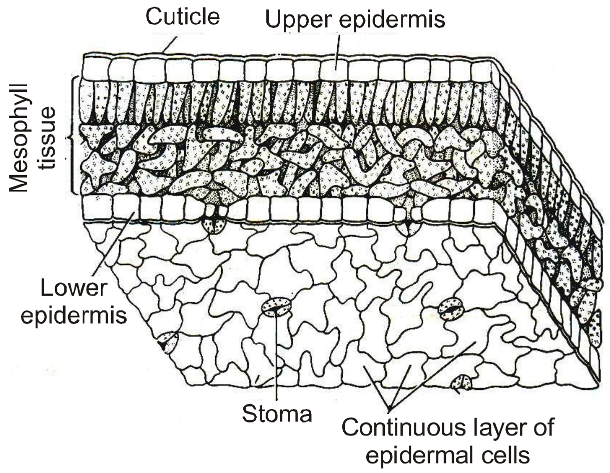
  C. The vascular/conducting tissue system.

**A. Epidermal tissue system**

It comprises the following :

**(a) Epidermis**

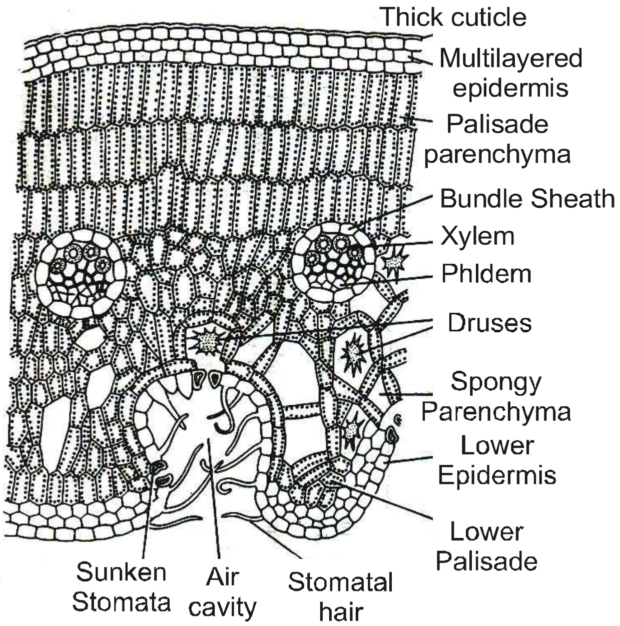
- The epidermis (**epi** : upon ; **derma** : skin) is the **outermost layer** of the plant body, which is direct contact with external environment.
- It is made up of **elongated, compactly arranged cells** which constitute a continuous layer without any intercellular spaces.
- The cells have a **large, central vacuole** surrounded by a thin layer of protoplasm.




**Three dimensional structure of leaf showing epidermal tissue system**

- The epidermis may also be **multilayered** as in the **aerial roots of** *Orchids* and **leaves of** *Nerium* and *Ficus*.
- The outer wall of epidermis is **thick** and usually covered by a **cuticle** formed by the deposition of a **waxy material** secreted in the epidermal cells. **The cuticle is thickest in the xerophytic plants.**
- Some epidermal cells of certain **monocots** (grasses, maize, sugarcane) are comparatively **large, vacuolated** and **thin–walled.** These are called **bulliform** or **motor cells.** These cells **store water** and **help in closing and opening of leaves due to changes in turgor.**
- The outermost layer of roots is referred to as **epiblema** or **piliferous layer.** There are **no stomata** and **cuticle** on the epiblema.

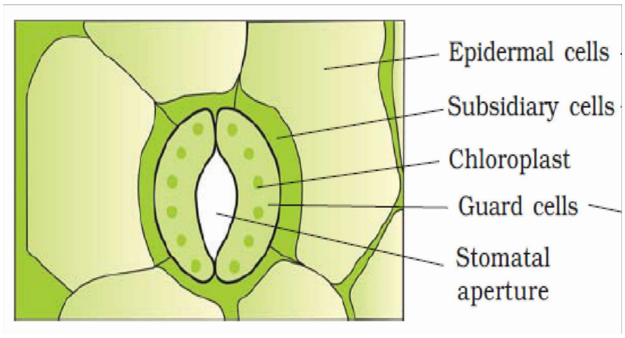
- In some roots a single or a few layers just below the epiblema are found. It is called **exodermis.** It corresponds to the hypodermis of the stem. The cells of exodermis are **thick–walled.**




**Part of *Nerium* leaf showing thick cuticle and multilayered epidermis**

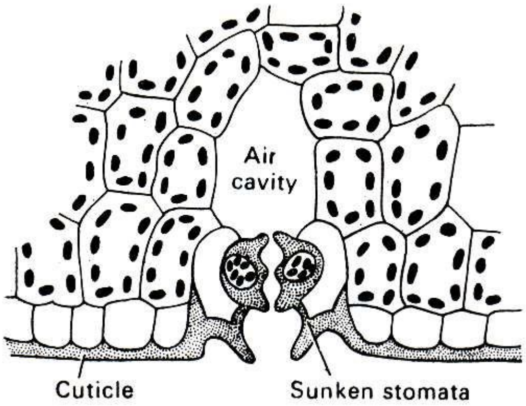
**(b) Stomata**

- Stomata are **very small openings** found in the **epidermis** of green aerial parts of the plant especially the leaves.
- Stomata are not present in **roots** and **non–green parts of the stem.**
- Pore of each stoma is surrounded by **two kidney shaped** (= semilunar) cells, called **guard cells.**
- The guard cells are **living** and contain **chloroplasts.** The inner walls are **thicker** than the outer walls.
- The guard cells regulate the opening and closing of the stomatal pores.



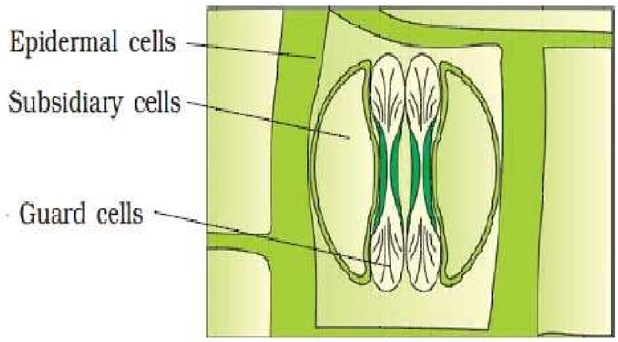

**Stomata with bean-shaped guard cells**

- In **xerophytes** the stomata are **sunken** in rooves due to which **rate of transpiration is greatly reduced.**




**Part of T.S. of Agave leaf showing sunken stomata and substomatal cavity**

- In **some monocots** e.g.; doob grass, maize the guard cells are **dumb–bell shaped.**




**Stomata with dumb-bell shaped guard cell**

- In plants outside the guard cell but attached to them are present some specialized jepidermal cells, which are called **subsidiary cells** or **accessory cells.**
- In **dicot leaves** the somata are found **scattered,** while in **monocot leaves** they are found in **rows.**
- Usually stomata remain closed at night but remain open during daytime.
- When the guard cells become **turgid,** the stomata are **open;** when the guard cells become **flaccid** they are **closed.**
- Stomata are **most abundant in the lower epidermis of a dorsiventral leaf** but **none** or **few** are present **in the upper epidermis.**
- In **submerged leaves no stomata are present.**
- In **floating leaves** they are present only on the **upper epidermis.**
- In xerophytic plants they are situated in pits or grooves.

**Functions**

- Stomata are the organs through which **evaporation of water** (transpiration) takes place.
- The **interchange of gases** ($O_2$ and $CO_2$) between the plant and atmosphere also takes place through them.

**(c) The epidermal appendages**

- In many plants epidermis bears outgrowths, called **trichomes** or **hairs** which vary markedly in their shape, structure and function.
- These may be **unicellular** or **multicellular, simple** or **branched, soft** or **stiff.**
- They are found on almost **all plant parts** and may be **temporary** or **permanent features.**

**Functions**

- Trichomes help in **checking excess loss of water** (reduction of water loss).
- Trichomes help in **protection, dispersal of seeds** and **fruits.**

**(d) Root hair**

- The epidermis of roots bears root hair in the specialized region – **the root hair zone.**
- The root hairs are formed due to the elongation of the **epidermal cells** and are **not protuberances** or **appendages.**
- The thin wall is made up of **cellulose** and **pectic materials.**
- The root hairs are **ephemeral** (short lived) **structures.**

**Functions**

- It play an important role in **anchoring** the plant body in the soil besides **absorbing water** and **mineral solution** from it.

**Functions of Epidermal tissue system**

- Epidermis is a **protective layer** and protects the plant from severe **environmental factors** and **mechanical injury.**
- The **stiff** and **sharp hairs** on the epidermis **protect the plant from grazing by animals.**
- The **cuticle** on epidermal cells **retards the rate of transpiration.**
- The **chloroplast** containing epidermal cells manufacture food material.

**B. Ground or fundamental tissue system**

- The ground tissue system forms the **main bulk of the plant body.**
- It includes all the tissues **except epidermis** and **vascular bundles.**
- It is **partly derived** from the **periblem** and **partly** from the **plerome.**
- The primary function of this tissue system is **storage** and **manufacture of food material.**
- This system has different kinds of tissues such as **parenchyma, collenchyma** and **sclerenchyma;** of these parenchyma is most abundant and carries out a variety of functions.
- In **monocotyledonous stem** (with scattered vascular bundles) the ground tissue is **not differentiated** into cortex, pericycle and pith.
- In **dicot stems** and **dicot** and **monocot roots** (in which vascular bundles are in a ring), the ground tissues constitute the following parts :

  (a) Cortex

  (b) Pericycle

  (c) Medulla or Pith

**(a) Cortex**

It can be divided into hypodermis, general cortex and endodermis.

**(i) Hypodermis**

- It is found just **below the epidermis.**
- It is made up of **collenchymatous cells in a dicot stem** and of **sclerenchymatous cells in a monocot stem.**
- Hypodermis remains **absent in roots.**
- Hypodermis **protects the internal tissues** and **gives mechanical support to the peripheral region.**

**(ii) General cortex**

- This part lies between **hypodermis** and **endodermis.**
- It is made up of **parenchymatous cells.** Sometimes, the cell contain **chloroplasts.**
- General cortex provides **mechanical support** and **stores food material.**

**(iii) Endodermis**

- Endodermis is **single layered** structure which separates cortex from stele.
- Endodermis composed of compactly arranged **parenchyma cells.**
- The cells of endodermis are **barrel–shaped, without intercellular spaces, living** and containing **starch.** (Hence it is known as **starch sheath**).
- **cells cutit**in known as **casparian bands** or **casparian strips** (as were discovered by **Casperi in 1865**).

**Functions**

- Endodermis may serve as a **passage for water** from the cortex to the protoxylem of root.
- It may act as a **water–tight jacket** between the xylem and surrounding tissues.
- It may act as a **storage tissue.**
- It may serve as **protective layer.**

**(b) Pericycle**

- Pericycle is situated in between **endodermis** and **vascular bundles.**
- The cells of pericycle are **parenchymatous** or **sclerenchymatous.**
- In **dicot stem it is multi–layered** while it is **not distinct in monocot stems.**
- Pericycle is present in most of the roots **except in roots of parasitic plants and hydrophytes.**
- In dicotyledonous stems it occurs as a **cylinder** which encircles the **vascular bundle** and the **pith.**

**Functions**

- In **angiosperms,** pericycle gives rise to **lateral roots.**
- In **dicot roots** it gives rise to a portion of the **vascular cambium** and later the whole of **cork cambium.**
- Its other functions are **storage, mechanical** and **secretion.**

**(c) Pith or Medulla**

- The pith or medulla is the **central core** of the stem and the root.
- It is usually made up of **large parenchyma cells** with **intercellular spaces.**
- In the **dicot stem** the pith is **large** and **well–developed.**
- In the **monocot stem,** due to scattered distribution of vascular bundles, it is **absent.**
- In the **dicot root pith is either small** or **absent,** while in the **monocot root a distinct pith is present.**
- In the **dicot stem** the pith extends towards the pericycle between the vascular bundles. The extensions are called **pith** or **medullary rays** which are made up of **parenchyma cells.**
- Medullary rays are not present in the **roots.**

**Functions**

- The function of the pith is to store various substances such as starch, mucilage, tanin, etc.
- Medullary rays transmit water and food material outwards to the peripheral tissues.

**C. Vascular tissue system**

- Central column of axis (root and stem) is called **stele,** which is made of number of vascular bundles, which constitute **Vascular tissue system.**
- The vascular bundle is having **xylem, phloem** and **cambium** (if present).
- Xylem may be **exarch** or **endarch.**
- In **roots,** xylem is **exarch** or **centripetal,** i.e.; protoxylem or first formed xylem is towards periphery.
- In **stem,** xylem is **endarch** or **centrifugal,** i.e.; protoxylem is towards centre (pith).
- If the **cambium is present** in between the xylem and phloem are said to be **open vascular bundle** (e.g.; dicots) **.**
- If the **camblum is absent** in between the xylem and phloem are said to be **closed vascular bundle** (e.g.; monocots).

### Types of vascular bundle

According to the arrangement of xylem and phloem vascular bundles are of three types :–

(a) Radial (b) Conjoint (c) Concentric

**(a) Radial**

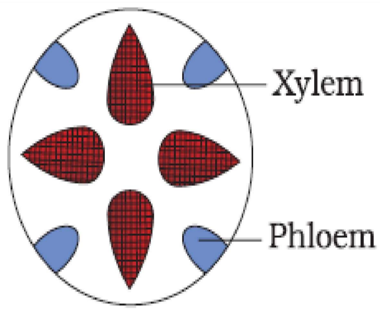
- When xylem and phloem are arranged in an **alternate manner on different radii,** such vascular bundles are called **radial.**
- All the roots of plants contains **radial vascular bundle.**
- The development of xylem in these vascular bundle is **centripetal.** Thus, these vascular bundles are called **exarch.**

**(b) Conjoint**

- When xylem and phloem are present on the **same radius,** this type of vascular bundles are known as **conjoint.**
- Conjoint vascular bundles are the characteristic feature of **stem.**
- Depending upon the **mutual relationship of xylem and phloem,** these are divided into two types:

**(c) Concentric**

- When xylem surrounds phloem completely or phloem surrounds xylem completely, such vascular bundles are called **concentric.**
- Concentric vascular bundles are **always closed.**

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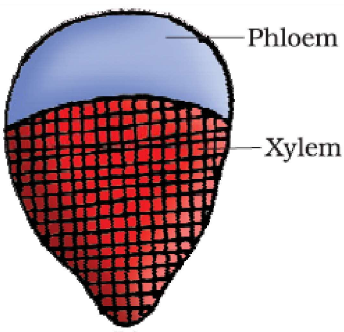


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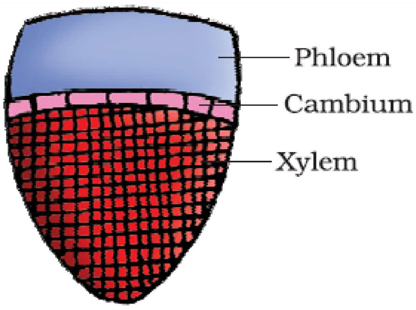



(c)

**Various types of vascular bundles :**

**(a) radial (b) conjoint closed (c) conjoint open**

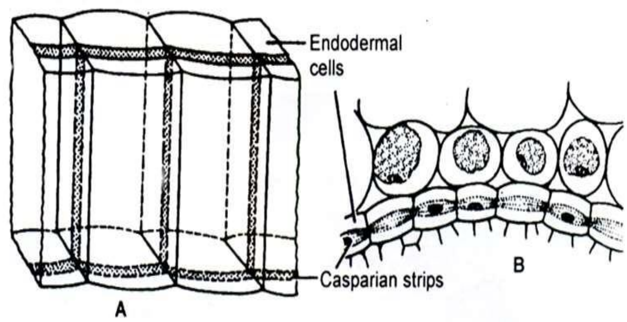
## DICOTYLEDONOUS ROOT

Internal structure of a typical dicotyledon root shows following features : -

1. **Epidermis :** It is **uniseriate** outermost layer. It comprising tubular living components. Cuticle and stomata are absent. Unicellular root hairs are formed due to elongation of some cells of epidermis.
2. **Cortex :** It is made up of parenchymatous cells with intercellular space.

   **Note :** The cells of outer part of cortex are suberized in old root. It is called exodermis.

   Exodermis found in some dicotyledon roots and most of the monocotyledon roots.
3. **Endodermis :** Inner most layer of cortex is known as endodermis. Casparain strips are present on radial and tangential wall of endodermis. These strips are made up of suberin. Casparian strips are discovered by Caspari.




Endodermal cells : Casparian strips in tangential and radial walls

- The cells of endodermis which are situated in front of protoxylem cells lack of casparain strips.

  These are called **passage cells.**

  The number of **passage cells** is equivalent to the **protoxylem cells** and number of rows of root hair equivalent to protoylem cells.

- Passage cells provide path to absorbed water from cortex to pericycle.

**Note :**

(1) Root hairs are linearly arranged on root apex.

(2) Casparian bands and passage cells are well developed in monocot root.

(3) Endodermis acts as a water tight jacket and prevents radial conduction of water

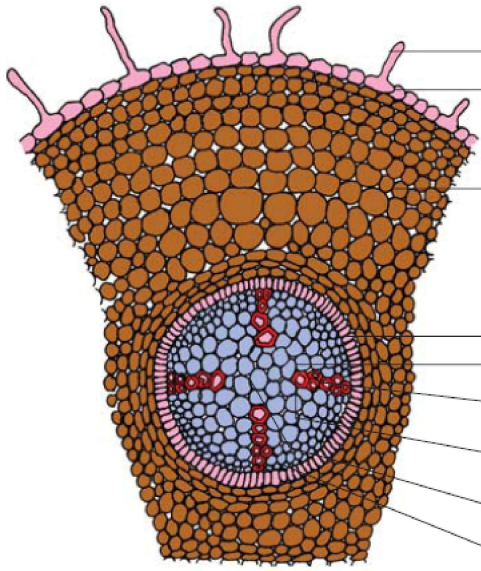



**Fig: T.S. - Dicot root (Primary)**

4. **Pericycle :** It is few thick layered. It is composed of **prosenchyma.**

- **Lateral** roots are originated from the part of **pericycle** which is lying opposite to protoxylem. Thus lateral root are **endogenous** in origin.

- A few mature cells of pericycle usually opposite to protoxylem, become meristematic. these cells divide by periclinal divisions and form some layers of cells. these divisions are followed by anticlinal divisions forming a primordium which grows to form a lateral root.

**Note :** Adventitious root are also **endogenous.** Because these are originated from stellar region.

- Some part of vascular cambium in root is originated from pericycle.

5. **Vascular Bundles :** Vascular bundles are **radial** and **exarch.** Xylem and phloems are separate and equal in number. The numbers of xylem bundles are usually two to four (**diarch** to **tetrarch upto hexarch**).

- But exceptionally, **Ficus** (Banyan tree) root is **polyarch.**

- Parenchyma which is found between xylem and phloem, called **Conjunctive tissue.**

- Vascular cambium is developed from it.

6. **Pith :** In dicot root pith is **small or inconspicous.**

## MONOCOTYLEDONOUS ROOT

- The internal structure of a typical monocotyledon root is similar to dicotyledon root.

  **But**

(1) Number of xylem bundles are **more than six** (Polyarch) in monocotyledon root (**exceptionally** the number of xylem bundles are two to **six** in **onion**).

(2) Pith is **well developed** in monocotyledon root

(3) Only lateral roots are originated from pericycle.

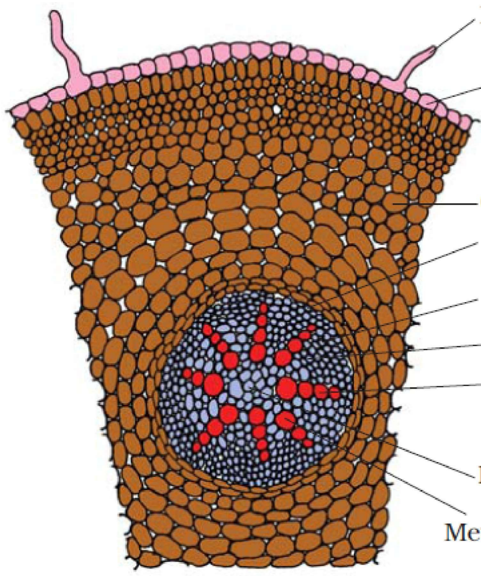



**Fig: T.S. - Mononcot root**

**Difference between dicot root and monocot root**

| S. No. | Character | Dicot root | Monocot root |
|---|---|---|---|
| 1 | Pericycle | Gives rise to secondary roots and lateral meristem | Gives rise to lateral roots only. |
| 2 | Vascular bundles | Diarch to hexarch | Polyarch |
| 3 | Cambium | Develops at the time of secondary growth | Absent |
| 4 | Pith | Absent or poorly developed | Fully developed |

## DICOTYLEDONOUS STEM

**I. Scattered Vascular Bundles :** In some of dicotyledon stem, vascular bundles are not arranged in a ring, they are **Scattered** in the cortex.

Example : - Thalictrum, Nymphaea.

**II. Phloem on innermost radius : Anomalously** in some plants, the position of phloem is towards the inner side of xylem. Such type of phloem is called **Internal or intraxylary phloem.** Because, this phloem lies towards the pith, so it is also known as **medullary phloem.**

Example : **Calotropis, Capsicum, Leptadaenia,** etc.

**III. Medullary vascular Bundle :** In some plants vascular bundles are present in pith. These are found in addition to normal ring of vascular bundles. These are called **medulllary vascular bundles.**

Example : Amaranthus, Boerhaavia, Chenopodium, Mirabilis, Achyranthes, Bougainvillea, Raphanus sativus.

**IV. Cortical Vascular Bundles :** Some of the vascular bundles are also present in the cortex of plants except the ordinary ring of vascular bundles. They are known as **cortical vascular bundles.**

Example : Casuarina, Nyctanthes and Lathyrus etc.

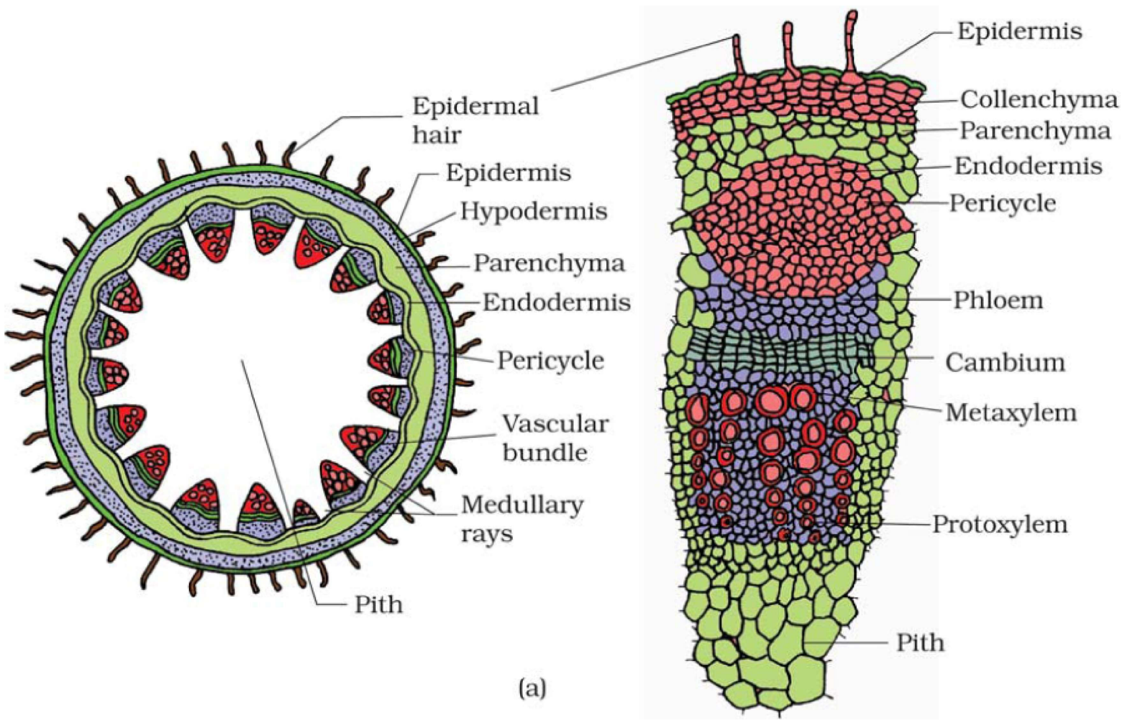
**V. Polystelic condition :** Each vascular bundle is surrounded by a separate endodermis and pericycle in some plants. Hence, each vascular bundle is a **stele.** It is the normal situation in pteriodphytes but in some dicotyledons it is present abnormally.

Example : - Primula, Dianthera

**VI. Exclusively xylem vascular Bundle :** Abnormally, some vascular bundles are only formed by xylem except the normal vascular bundles. Phloem is not present in these vascular bundles. Example : - Paonia

**VII. Exclusively phloem vascular Bundle :** Abnormally, some vascular bundles are only formed by phloem except normal vascular bundles in some plants. Xylem is not present in these vascular bundle.

Examples : - Cuscuta & Ricinus communis




(a)

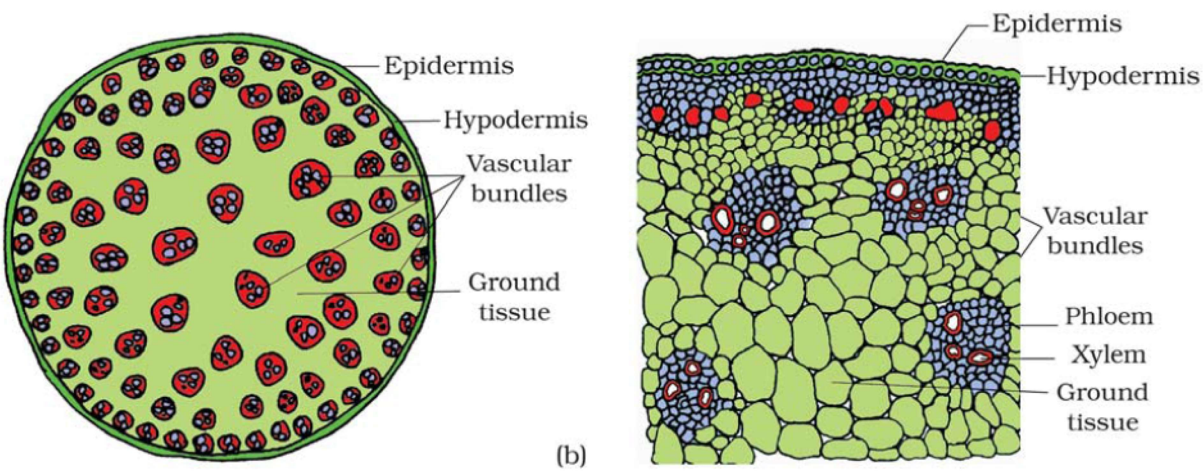



**Figure 6.7** T.S. of stem : (a) Dicot (b) Monocot

## MONOCOTYLEDONOUS STEM

**Vascular bundle situated in Ring :** Normally vascular bundles are found in monocotyledon stem in scattered form but in the stem of some monocotyledon plants vascular bundles are arranged in ring. Such as Triticum, Secale, Hordeum, Avena, Oryza etc. Members of family Gramineae.

## SPECIAL POINT

1. Monarch condition → in **Trapa root**
2. Triarch condition → in **Pisum root**
3. Tetracrch condition → in **Helianthus annus, Cicer arietenum root**
4. **Waiting meristem concept :** This concept was given by **Buvat.** According to this, there is an inactive centre in the shoot apex which is known as waiting meristem and it acts as reservoir of active initials and on induction it give rise to reproductive apex.
5. **Tannin** is found in latex of **banana.** When it comes in contact with air it gets oxidized and becomes reddish brown in colour.
6. Tannin glands are found in **Camellia.** These glands are **schizogenous** in origin.
7. Salt glands are found in **Tamarix** which secretes **sodium chloride.**
8. **Chalk glands** are found in plants of **plumbaginaceae** family which secretes **calcium carbonate.**
9. Maltilayered (14 to 15 layers) epidermis is found in **Peperomia leaves.**
10. The most durable wood is **Tectona grandis.**
11. Tracheids are the chief water transporting elements in gymnosperms.
12. Phloem is embedded into the secondary xylem in some plants. Such phloem is called **included phloem** or **interxylary phloem.** This is secondary anomalous structure.

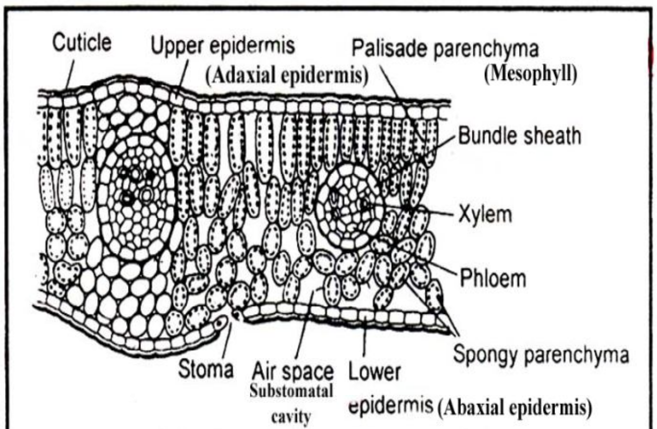
    **Example : Leptadaenia, Salvadora** etc. dicot stem.
13. Pericycle is absent in roots and stem of some aquatic plants.
14. In some monocotyledonae roots, pith is **sclerenchymatous**. Ex. **Canna.**
15. A nectar secreting glands cell contains granular cytoplasm and a large conspicuous nucleus.

## DORSIVENTRAL (DICOTYLEDONOUS) LEAF

- Cuticle is present on both surfaces but cuticle of upper surface is thicker.
- Dorsiventral leaves are mostly **hypostomatic** i.e. stomata present on lower surface.

  **Note :** In amphistomatic dorsiventral leaves stomata are more on lower surface.
- Mesophyll of these leaves is divided into two regions - Palisade tissue and spongy tissue.

- Palisade tissue is found towards upper surface. These cells have more chloroplasts. Spongy tissues is found towards lower surface and have large intercellular space.

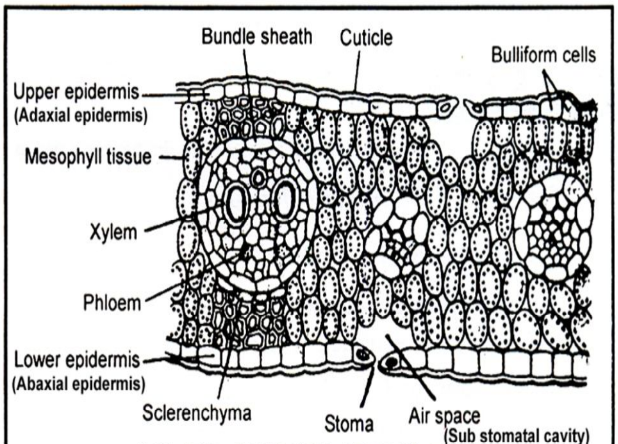



V.S./T.S OF DORSIVENTRAL LEAF

## ISOBILATERAL (MONOCOTYLEDONOUS) LEAF

- The thickness of cuticle on the both surface is equal.
- Distribution of stomata on both surface's are equal.

  **Note :** Isobilateral leaves are **Amphistomatic** i.e. stomata present on both sides.
- Mesophyll of isobilateral leaves is not differentiated into palisade and spongy tissues. It is completely made up of spongy tissues. **Palisade tissues are absent.**




(V.S./T.S. OF ISOBILATERAL LEAF

- **Bulliform cells :** Large cells are found in the epidermis of psammophytic (desert) grasses which are filled by liquid or empty (mostly) and colourless are called bulliform cells or motor cells. When the bulliform cells in the leaves have absorb water and become turgid the leaf surface is exposed. When they are flaccid due to water stress they make the leaf curl and minimize water loss.

  **Example : Ammophila, Poa, Empectra** and **Agropyron** etc. are Psammophytic grasses

## VASCULAR BUNDLES OF LEAVES

- Similar types of vascular bundles are found in both dorsiventral and isobilateral leaves. Vascular bundles of leaves are **conjoint, collateral** and **closed.**
- Protoxylem is situated towards the adaxial surface and protophloem towards the abaxial surface in the vascular bundle.
- The sizes of the vascular bundle are dependant on the size of vein. The veins vary in thickness in the reticulate venation. Thus different size vascular bundles are present in dicot while in parallel venation similar size vascular bundle are present.
- Vascular bundles are surrounded by a **bundle sheath.** Bundle sheath is **chlorenchymatous** in C-4 plants.
- Epidermis of **Nerium** (both upper & lower) and **Ficus** (only upper epidermis) becomes **multilayered.** This is an adaptation to reduce transpiration.

## SPECIAL POINTS

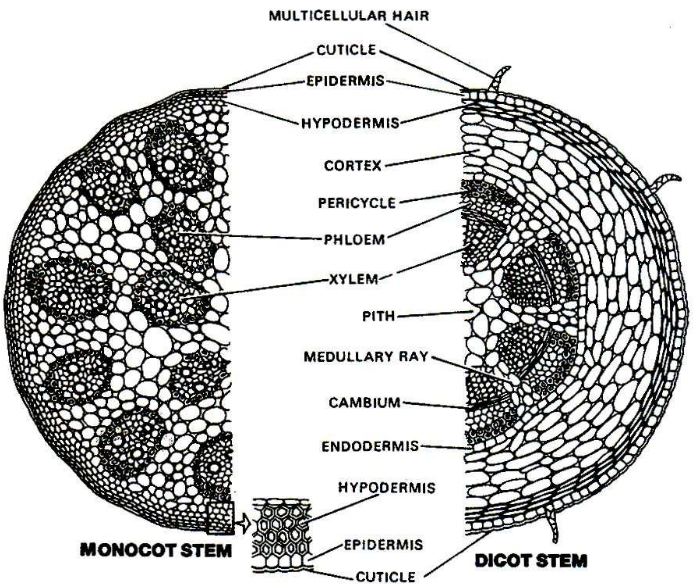
1. Xerophytes with isobilateral leaves contain palisade on both sides of leaf.

   Examples : Eucalyptus & Nerium.
2. Desert grasses contain palisade like spongy tissue
3. **Unifacial or cylindrical leaf :** In these leaves there are no differentitation of upper surface and lower surface.

   Example : Onion, Garlic
4. **Albascent leaf :** Palisade tissue is restricted in half part of leaf so half part appears more green and other half appears less green.

   Example : Abutilon

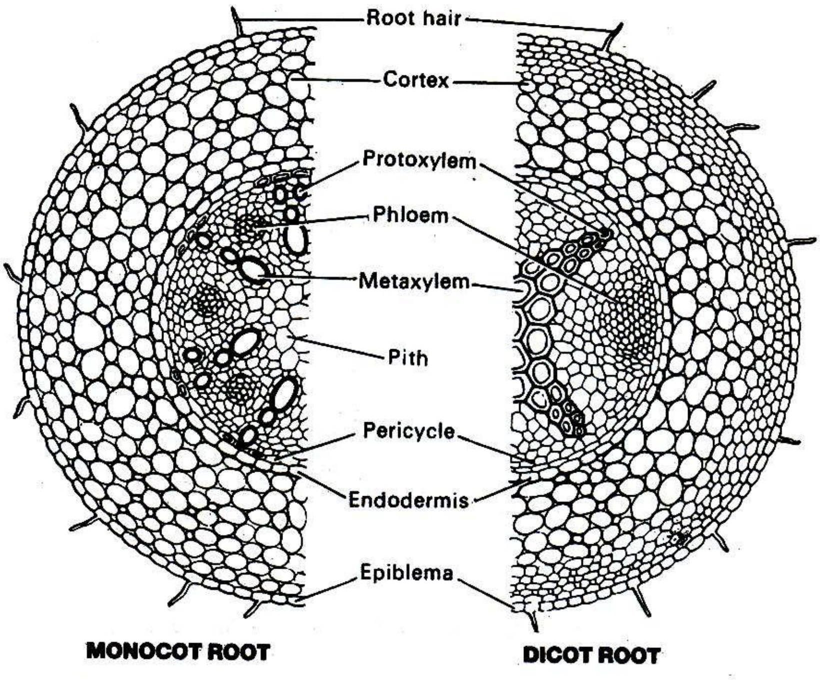
| Sr. No. | Characters | Monocotyledonous stem | Dicotyledonous stem |
|---|---|---|---|
| 1 | Epidermis | Present, cells comparatively smaller and without hair | Present, cells larger and with hair |
| 2 | Hypodermis | Sclerenchymatous | Collenchymatous |
| 3 | Cortex | Absent, but ground tissue is present from hypodermis to the centre of stem | Made up of several layers of parenchymatous tissue |
| 4 | Endodermis | Absent | One layered, starchy sheath which is usually not well differentiated |
| 5 | Pericycle | Absent | Made up of 1 or more layers of parenchymatous and/or sclerenchy-matous cells |
| 6 | Medullary rays | Absent | Found in between vascular bundles |
| 7 | Pith (Medulla) | Absent | Made up of parenchymatous cells situated in the centre of stem |
| 8 | Vascular bundles | (a) Scattered | (a) In a ring |
| | | (b) Conjoint, collateral, closed | (b) Conjoint, collateral and open |
| | | (c) Larger towards centre | (c) All of same size |
| | | (d) Oval | (d) Usually wedge - shaped |
| | | (e) Bundle sheath present | (e) Bundle sheath absent |
| | | (f) Phloem parenchyma absent | (f) Phloem parenchyma present |
| | | (g) Xylem vessels either Y or V shaped | (g) Xylem vessels more radial |




**Comparison of the T.S. of monocot stem (A) and dicot stem (B)**

**Differences between monocot and dicot root**

| Sr. No. | Characters | Monocot root | Dicot root |
|---|---|---|---|
| 1 | Cortex | Less developed | Well developed |
| 2 | Endodermis | Casparian strips present in radial and tangential walls | As in monocot root |
| 3 | Pericycle | Produces lateral roots | Produces lateral roots, vascular cambium and cork cambium |
| 4 | Vascular bundles | Numerous (polyarch) | Usually 2 - 6 |
| 5 | Cambium | Absent | Appear later as a secondary meristem |
| 6 | Pith | Large and developed | Small or absent |
| 7 | Secondary growth | Not found | Found |
| | | (a) Scattered | (a) In a ring |
| | | (b) Conjoint, collateral, closed | (b) Conjoint, collateral and open |
| | | (c) Larger towards centre | (c) All of same size |
| | | (d) Oval | (d) Usually wedge - shaped |
| | | (e) Bundle sheath present | (e) Bundle sheath absent |
| | | (f) Phloem parenchyme absent | (f) Phloem parenchyma present |
| | | (g) Xylem vessels either Y or V shaped | (g) Xylem vessels more radial |



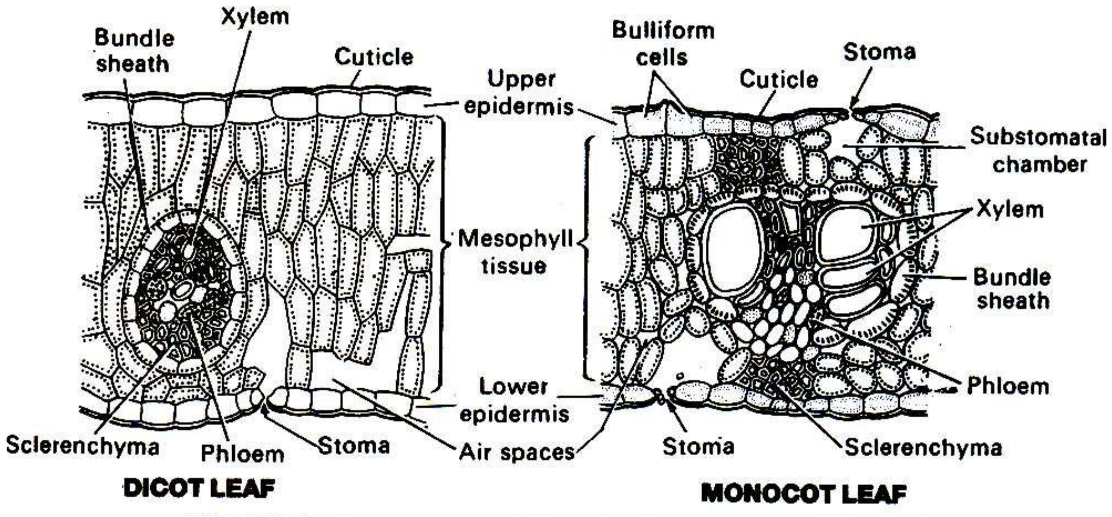

**Comparison of the T.S. of monocot and dicot roots**

## Differences between anatomy of root and stem

| Sr. No. | Characters | Root | Stem |
|---|---|---|---|
| 1 | Epidermis or Epiblema | Epiblema or piliferous layer without cuticle | Epidermis usually with cuticle |
| 2 | Hair | Unicellular | Multicellular |
| 3 | Chlorenchyma in cortex | Absent | Usually present in young stems but absent in old stem |
| 4 | Endodermis | Very distinct | Poorly developed or absent |
| 5 | Vascular bundle | Radial | Conjoint, collateral or bicollateral or concentric |
| 6 | Xylem | Exarch | Endarch |

## Differences in the anatomy of dicot and monocot leaves

| Sr. No. | Characters | Dicot leaf | Monocot leaf |
|---|---|---|---|
| 1 | Type of leaf | Dorsiventral | Isobilateral |
| 2 | Stomata | Usually more on lower epidermis (hypostomatic) | Equal on lower and upper epidermis (amphistomatic) |
| 3 | Mesophyll | Made up of two types of tissues<br>(a) Palisade tissue<br>(b) Spongy parenchyma with large | Only spongy parenchyma is present which has very small intercellular spaces. |
| 4 | Bundle sheath | Made up of parenchyma. Just above and below the vascular bundle some parenchymatous cells or collenchymatous cells are present | Made of parenchyma but just above and below the vascular bundles are found sclerenchymatous cells (up to |
| 5 | Bulliform cells | Absent | Present |




**Detailed structure of a part of T.S. of mango leaf**

## SECONDARY GROWTH

- "**Secondary growth is increase in girth or diameter of axis (root and stem) of the plant by formation of secondary tissue by activity of lateral meristem** (vascular cambium and cork cambium)."

  The secondary tissue is of two types :–

  **1. Secondary tissue formed by true cambium** or **vascular cambium** or **intrastelar cambium.**

  e.g.; Secondary xylem and secondary phloem.

  **2. Secondary tissue formed by cork cambium** or **phellogen** or **extrastelar cambium.**

  e.g.; Phellem or cork cells and phelloderm (sec. cortex).

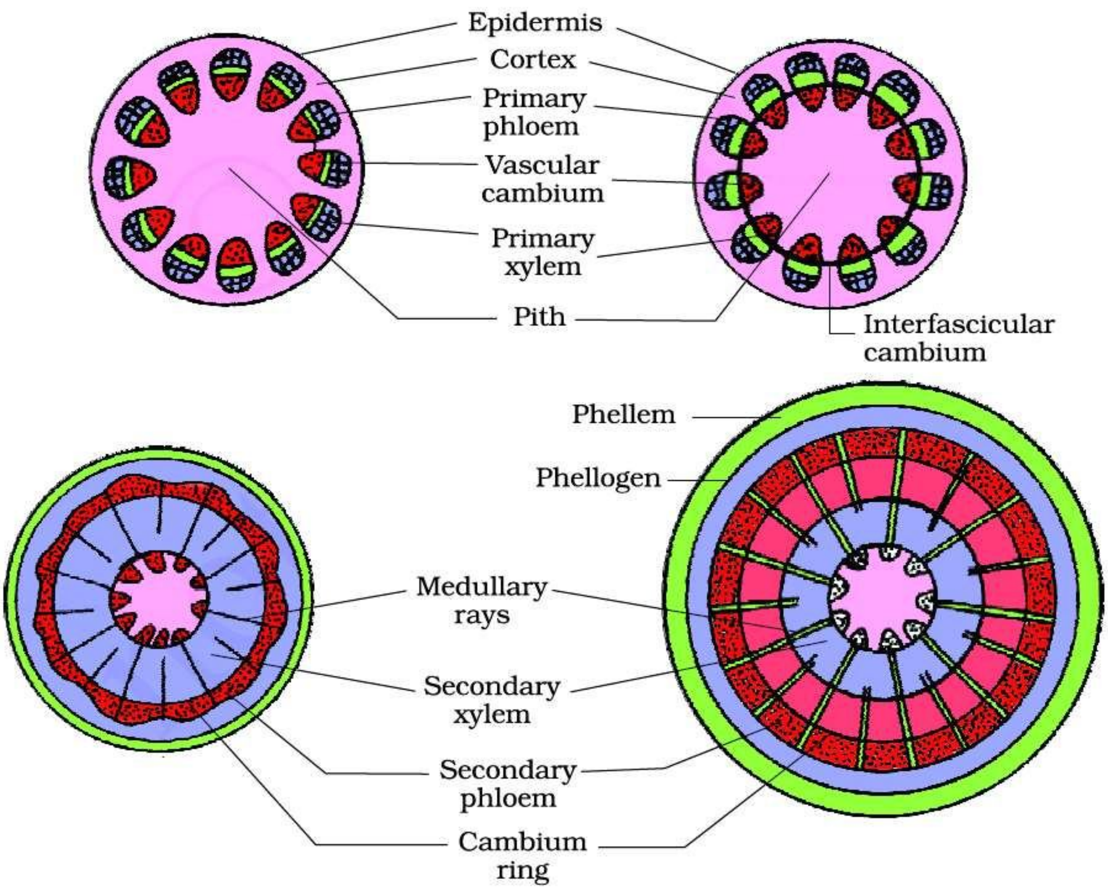
## (A) SECONDARY GROWTH IN DICOT STEM

### (a) SECONDARY GROWTH BY VASCULAR CAMBIUM :

- The vascular bundles in dicot stem are **conjoint, collateral** and **open** and are arranged in a ring.
- The cambium present between xylem and phloem in vascular bundles is called **fascicular** or **intrafascicular cambium.**
- Some cells of medullary rays (i.e.; between vascular bundles) also become **meristematic** and this is called **interfascicular cambium.**
- Both these cambia collectively constitute a complete ring of **vascular cambium** or **intrastelar cambium.**
- The ring of vascular cambium or true cambium cuts off cells both on **outer side** and **innerside.**
- The cells cut off on outer side are **secondary phloem** and on inner side are **secondary xylem.**
- Amount of secondary xylem cut off is more than secondary phloem and thus with the formation of secondary tissue, **increase in girth** or **diameter** occurs, which is thus called **secondary growth.**
- Cambium cells are **rectangular, thin–walled, full of protoplasm** and having **meristematic activity.**

**Xylem and phloem rays (vascular rays)**

- At some place the cambium does not form secondary xylem and secondary phloem but form parenchymatous cells instead of xylem and phloem. Thus these cells form continuous strips from secondary xylem to secondary phloem and are called **secondary medullary rays.**
- These rays are arranged **radially.**
- Primary and secondary medullary rays conduct **food, water** and **minerals** from centre to periphery.

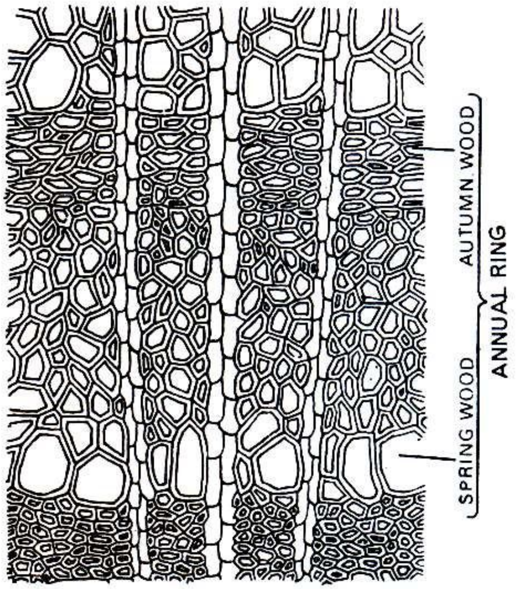



**Stages of secondary growth in a woody stem**

## ANNUAL RINGS OR GROWTH RINGS

- There is a marked difference in activity of cambium with change in season. In **spring,** the activity of cambium is **more** and hence the **wood elements are larger in size** with **wide lumen.** Moreover, the amount is more and the secondary xylem or wood formed during spring is called **spring wood.**
- The activity of cambium is **less** during **winter** or **autumn** and the **wood elements are smaller in size** with **narrow lumen.** Moreover, it is lesser in amount and the wood formed during winter or autumn is called **winter** or **autumn wood.**
- **Spring wood + Autumn wood** of a year constitute **annual ring.**
- Annual rings are **conspicious** in **temperate** (cold) **regions.**
- The age of tree can be determined by counting annual rings in oldest or basal portion of tree trunk. **Calculation of age of the tree by counting annual rings is called Dendrochronology.**

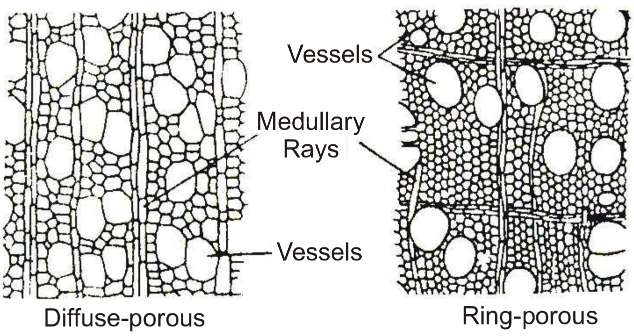
**Diagram representing annual rings in an old stem**




One of the annual rings

## POROUS AND NON–POROUS WOOD

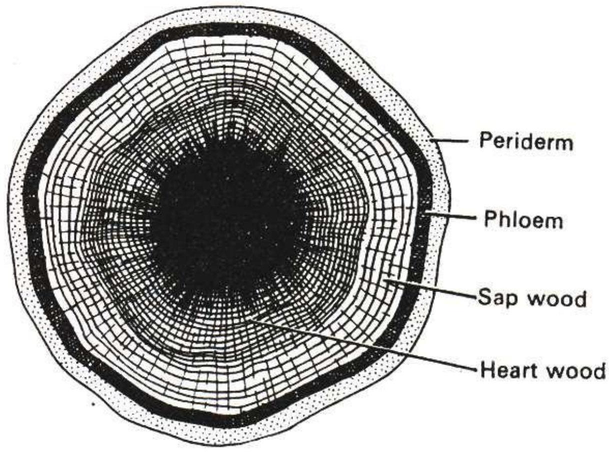
- The wood of **dicotyledonous trees** in which **vessels are present in the xylem is called porous wood.** It is also known as the **hard wood.**
- The wood in which **vessels are not found is called non–porous wood,** as in **gymnosperms.** It is also known as the **soft wood.**
- The porous wood is of two types. In some trees **large spring vessels are arranged more or less in a ring.** This type of wood is said to be **ring–porous.** In others, **the vessels have equal diameter and are uniformly distributed throughout the wood.** This wood is said to be **diffuse porous.**




**Diffuse–porous and ring–porous wood in transection**

## HEART WOOD AND SAP WOOD

- In perennial woody trees, the central portion of stem is darker in colour. Further it is hard and tough due to deposition of resins, tanins, gums and formation of tyloses. This central **hard, tough** and **darker** region constitutes **heart wood** or **duramen.**
- The conduction function of heart wood stops due to formation of tyloses in vessels and hence heart wood is **mechanical in function.** The heart wood is generally used for **making furniture.**
- The outer or peripheral portion of the trunk is **lighter in colour** and **soft** which performs the function of **conduction of water** and **minerals** and it is known as **sap wood** or **alburnum.** This wood is used for making **pulp wood, tool–handles** etc.



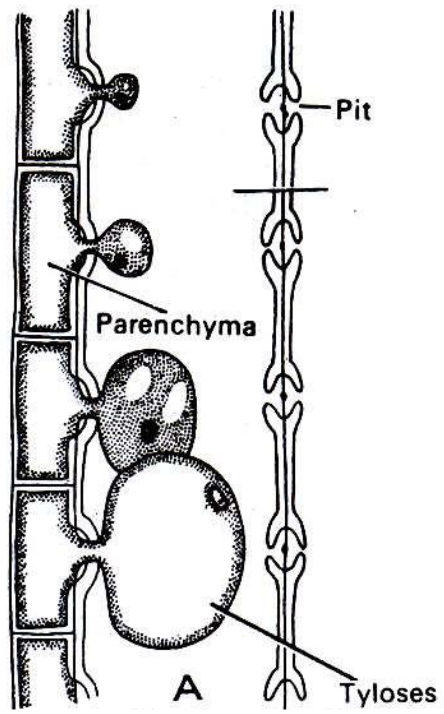

**T.S. of stem showing heart wood and sap wood**

**Differences between heart wood and sap wood**

| Sr. No. | Heart wood | Sap wood |
|---|---|---|
| 1 | Central region of the tree trunk, dark in colour | Outer region of the tree trunk, light in colour |
| 2 | Strong and durable | Not durable and strong |
| 3 | Provides mechanical support | Help in conduction of water |
| 4 | Cells contain tanins, resins, oils and pigments | Cells do not contain tanins, resins, oils and pigments |
| 5 | Cells are dead | Cells are living |
| 6 | Tyloses are present | Tyloses are absent |
| 7 | Important from economic point of view | Not important from economic point of view |

## TYLOSES

- These are **ballon–like** structures which are produced due to ingrowth of adjacent xylem parenchyma cells into the lumen of xylem vessels through pits.
- Tyloses are always found in **heart wood.**




**Tyloses L.S.**

**(b) SECONDARY GROWTH BY CORK CAMBIUM :**

In many woody plants further increase in girth takes place by formation of new tissue in extrastelar regions. These new tissues are called **periderm.** Periderm is made up of three tissues :–

**(i) Phellogen (=cork cambium)**

- It is a **secondary lateral meristem** that may arise from permanent living cells of **hypodermis** or **outer cortex.**
- It is composed of a **single layer of meristematic cells.**
- In **transverse section** the cells appear almost **rectangular** and **radially flattened.**
- Its cell divide in a tangential plane, cutting cells towards its inner as well as outer face.

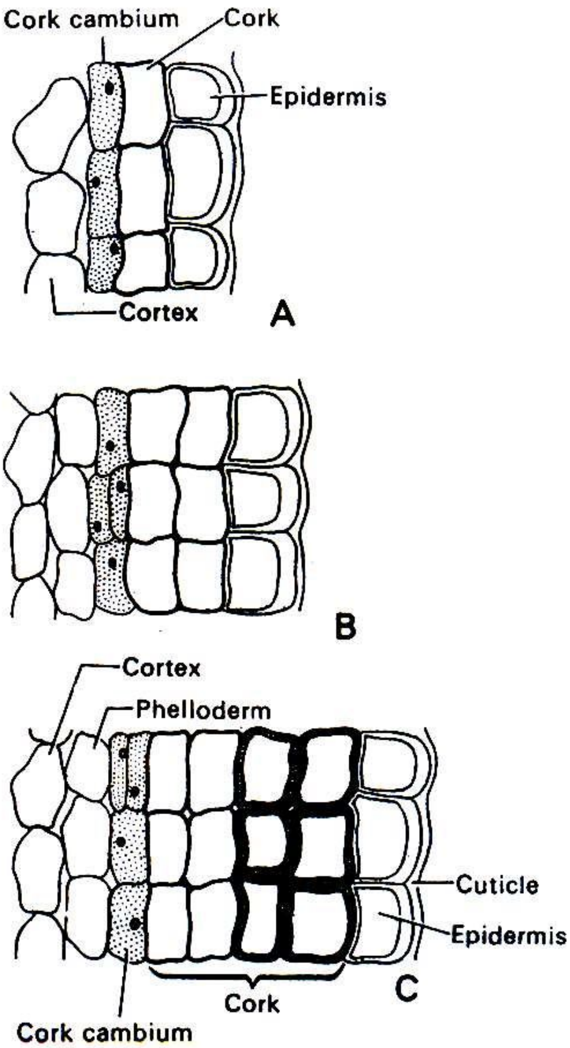
**(ii) Phellem (= cork)**

- These cells are formed as a result of **tangential and periclinal divisions of phellogen cells towards the outer face.**
- These cells are **compactly arranged** and have thin **cellulose walls** in the beginning.
- As they mature there is a **gradual loss of living matter** and cells get elongated **radially, vertically** or **tangentially.**

- The cell walls become **thick** because of development of fatty substance called **suberin.** Suberin is **impervious to water.**
- In *Quercus suber* which yields bottle cork, the cavities of cork cells are filled with air which makes the cork light in weight. It also provides **thermal insulating qualities.**

**(iii) Phelloderm (=secondary cortex)**

- Layers of thin walled cells cut off towards the **inner side** of the phellogen form **phelloderm.**
- The cells of this layer are **living** and possess **cellulose cell wall.**
- In some species these cell may contain **chloroplasts** and **starch.** This is also called **secondary cortex.**




**Formation of phellogn (A) and phelloderm (B) and phellem (C)**

## BARK

- Bark is a loose term and is used to define **all the tissues, outside vascular cambium.**

**Bark = Periderm + Cortex + Pericycle + Primary and secondary phloem.**

**Bark has two parts :–**

**(i) Outer bark**

- Outer bark is **dead.**
- All the tissue lies outside the cork cambium are called **outer bark.** It is also known as **Rhytidome.**

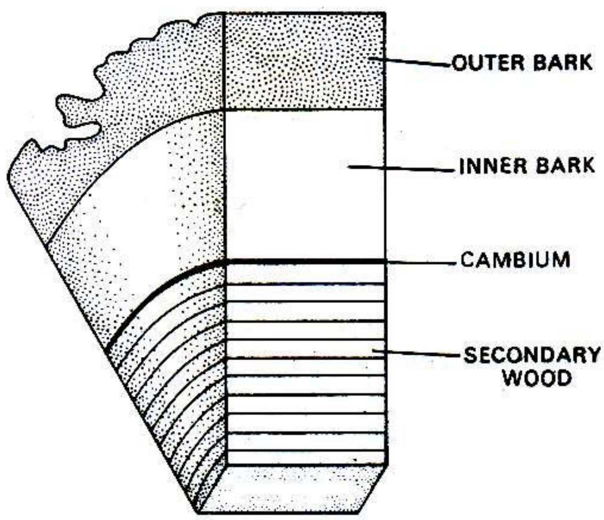
**(ii) Inner bark**

- The region in between the cork cambium and vascular cambium is called **inner bark.**
- Its most part is **living.**
- The main region of inner bark is the **secondary phloem** or **bast.**

✦ Thus bark constitute of both type of tissues – **living** and **non–living** (dead).

✦ A plant will die if we remove the complete bark of the plant because maximum loss of water occurs from this.

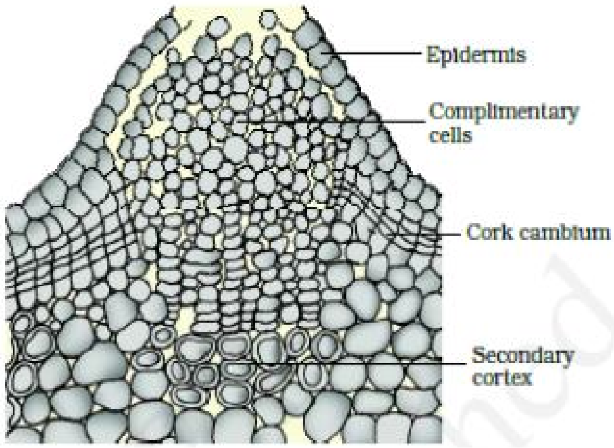
✦ If a ring of bark removed from the base of the plant, within a few days plant will die because phloem is separated due to this activity and plant comes in the state of deficiency of food.



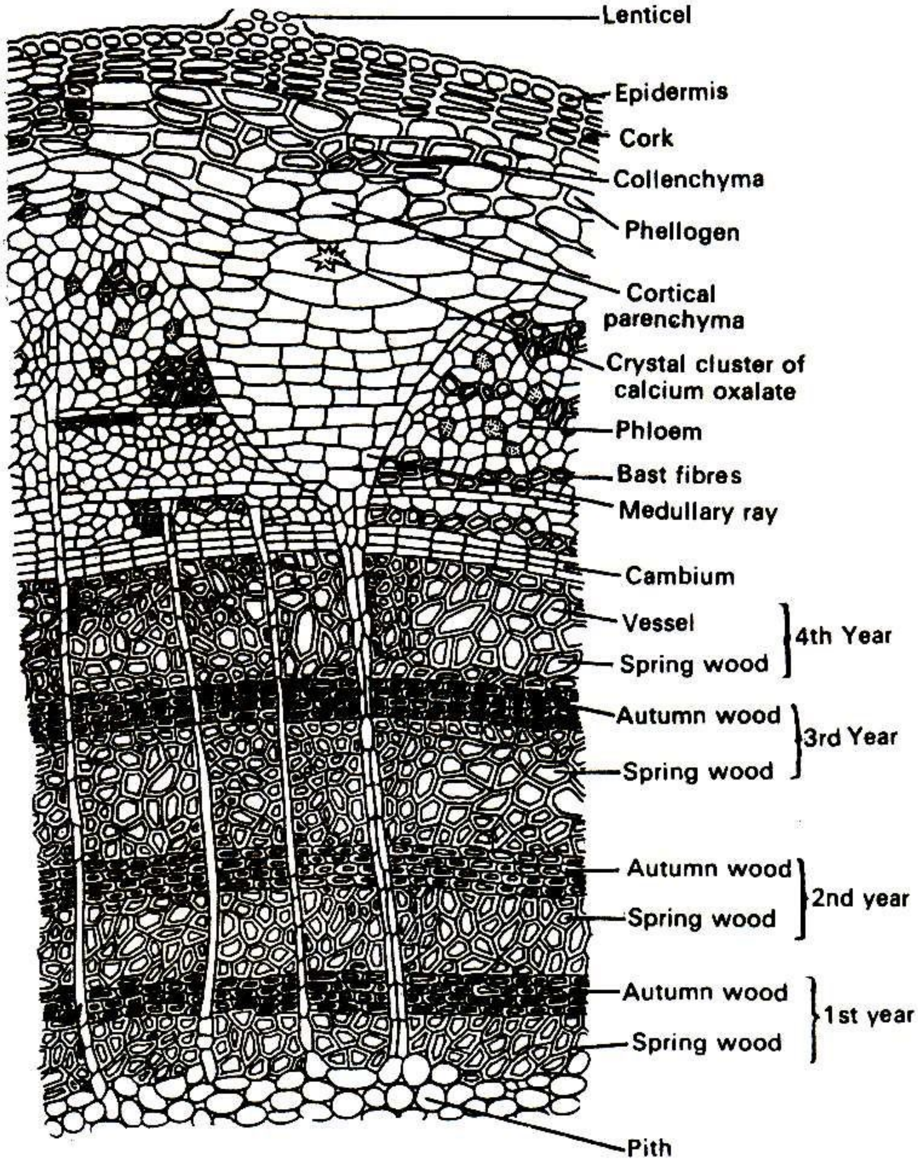

**Outer and inner bark**

## LENTICELS

- Lenticels are openings formed in the **bark** through which **exchange of gases** takes place.
- At each lenticel the cork cambium, instead of producing cork cells, forms **oval, spherical** or **irregular parenchymatous cells** which are **loosely arranged** with **abundant intercellular spaces** between them. This mass is known as the **complementary cells.**
- Lenticels are characteristics of **woody stem.** Lenticels help in **gaseous exchange** and **transpiration** (i.e.; lenticular transpiration)




**Lenticel**



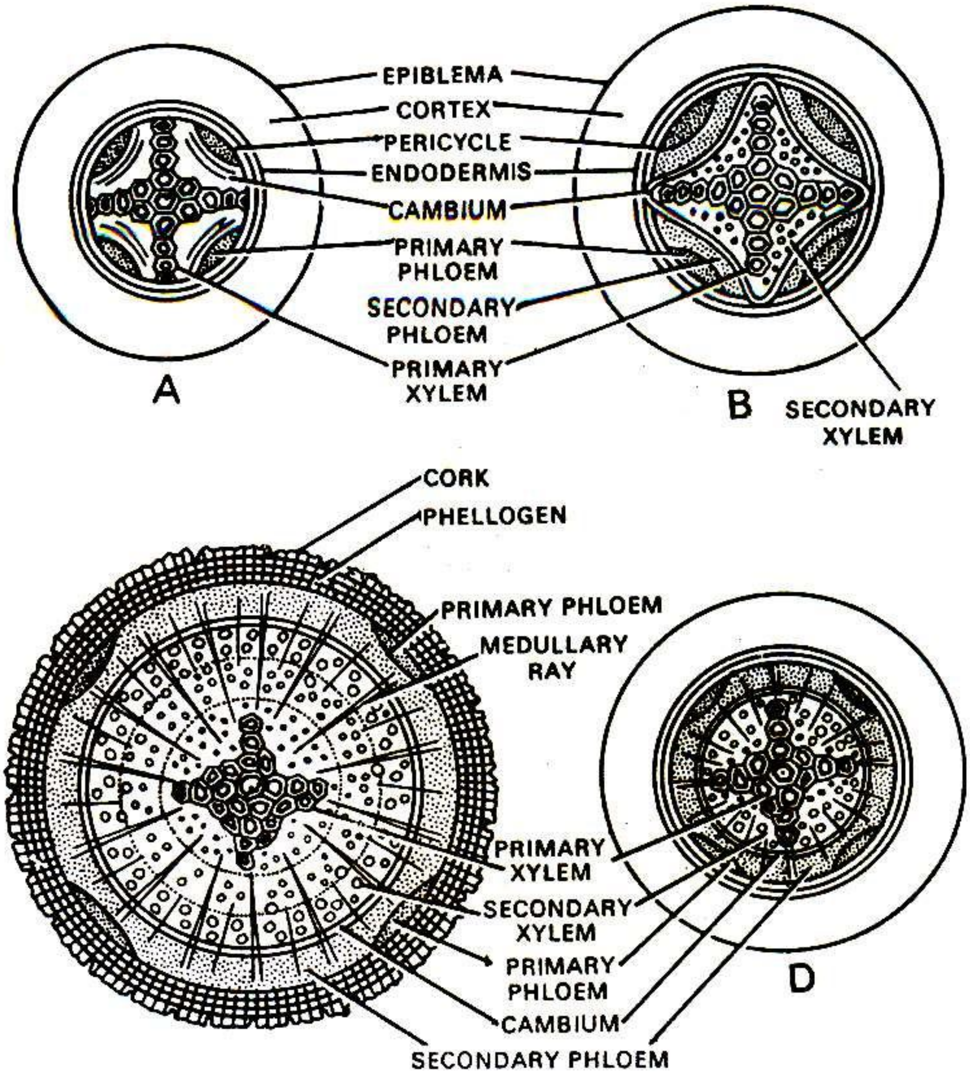

**T.S. of stem showing secondary growth**

## (B) SECONDARY GROWTH IN DICOT ROOT:

- Secondary growth is essential in roots to provide strength to the growing aerial parts of the plants and fulfill the requirement of water and minerals.
- Secondary growth is **not found in monocot roots.**
- It occurs due to the activity of **vascular cambium** and **cork cambium.**

### (a) ACTIVITY OF VASCULAR CAMBIUM :

- The **parenchymatous cells** on the inner side of the phloem become **meristematic** and gives rise to a **strip of cambium.**
- The **parenchymatous cells** lying in between xylem and phloem bundles also become **meristematic.**
- After this, the **portion of the pericycle** lying opposite the protoxylem becomes **meristematic** and forms a **strip of cambium.** Thus, a **wavy cambium** is formed extending over the xylem and down the phloem.
- It begins to cut off new cells on both sides but more on the inside.
- As a result of increased formation of new cells on the inner side the cambium and phloem are pushed outwards. The wavy cambium soon becomes **circular.**
- The whole of the cambium ring behaves in the same way as in the stem, giving rise to the **secondary xylem** on the inside and **secondary phloem** on the outside.
- The cambium forms **distinct radial bands of parenchyma** against the protoxylem. These are the **primary medullary rays.**

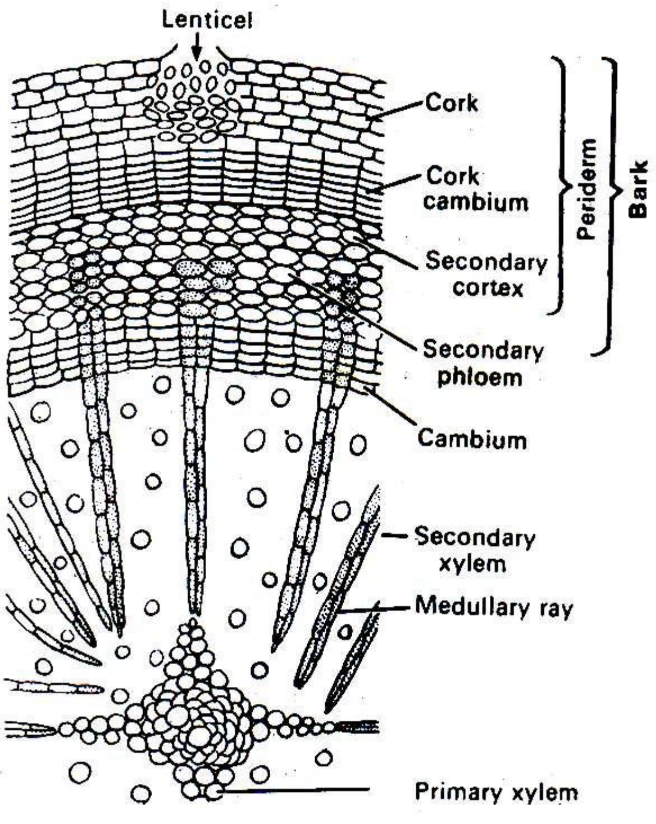



**Different stages in secondary growth of root**

- Some medullary rays are also formed by the cambium along the inner edge of the phloem and are called **secondary medullary rays.**
- Medullary rays are **larger** and **more prominent** in the **roots** than in the stems.
- The amount of secondary phloem is much less than the secondary xylem.
- The primary phloem gets crushed.

**(b) ACTIVITY OF CORK CAMBIUM :**

- The cork cambium may develop either from the **pericycle** or the **phloem.**
- The cork cambium produces a few **brownish layers of cork** (phellem) on the **outside** and the **secondary cortex** (phelloderm) on the inside.
- The cells of the secondary cortex **do not contain chloroplasts.**
- The bark forms only a thin covering. Here and there few lenticels may be developed.
- The cortex and endodermis become compressed and soon slough off.

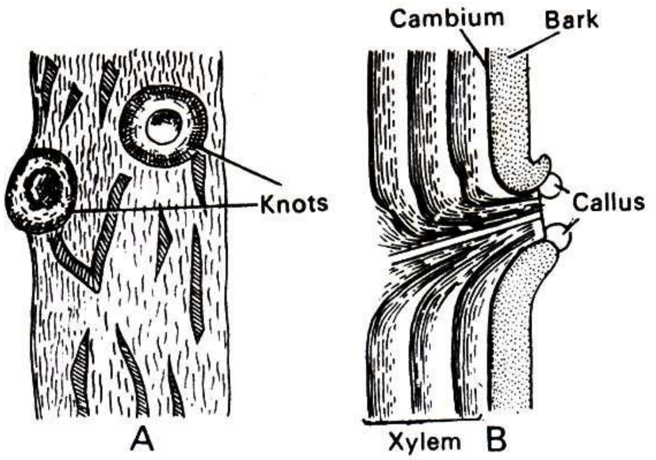



**Secondary grwoth in root**

**Functions of secondary meristem (Cambium)**

**Healing of wounds**

- Wounds in plants are formed due to **external injuries.**
- Healing of wounds is important for plant protection otherwise bacteria, fungi or other microbes may cause diseases. Besides this additional evaporation from the wound area may cause damage to the plants.
- If the wound is **superficial,** the exposed cells **die** and **dry up.**
- In case of **deep wounds,** the uninjured living cells below the wound become **meristematic** and produce a mass of undifferentiated parenchyma cells. This is known as **callus.**




**Knots in a stem A. Surface view, B. Callus formation as seen in T.S.**

**Leaf abscission** or **leaf fall**

- Leaf abscission is a common phenomenon in most of the **woody angiosperms** and **gymnosperms** (in some herbaceous angiosperms and pteridophytes, the leaves die on the plant without their fall or abscission).
- The falling or shedding of leaves from plant without causing any injury, is called **leaf abscission** or **leaf fall.**
- For separation of leaf, **abscission zone** is formed at the **base of petiole.**